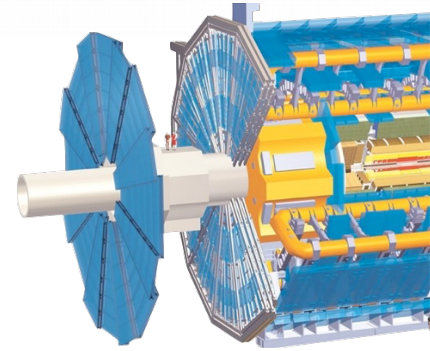


SEU Detector Update

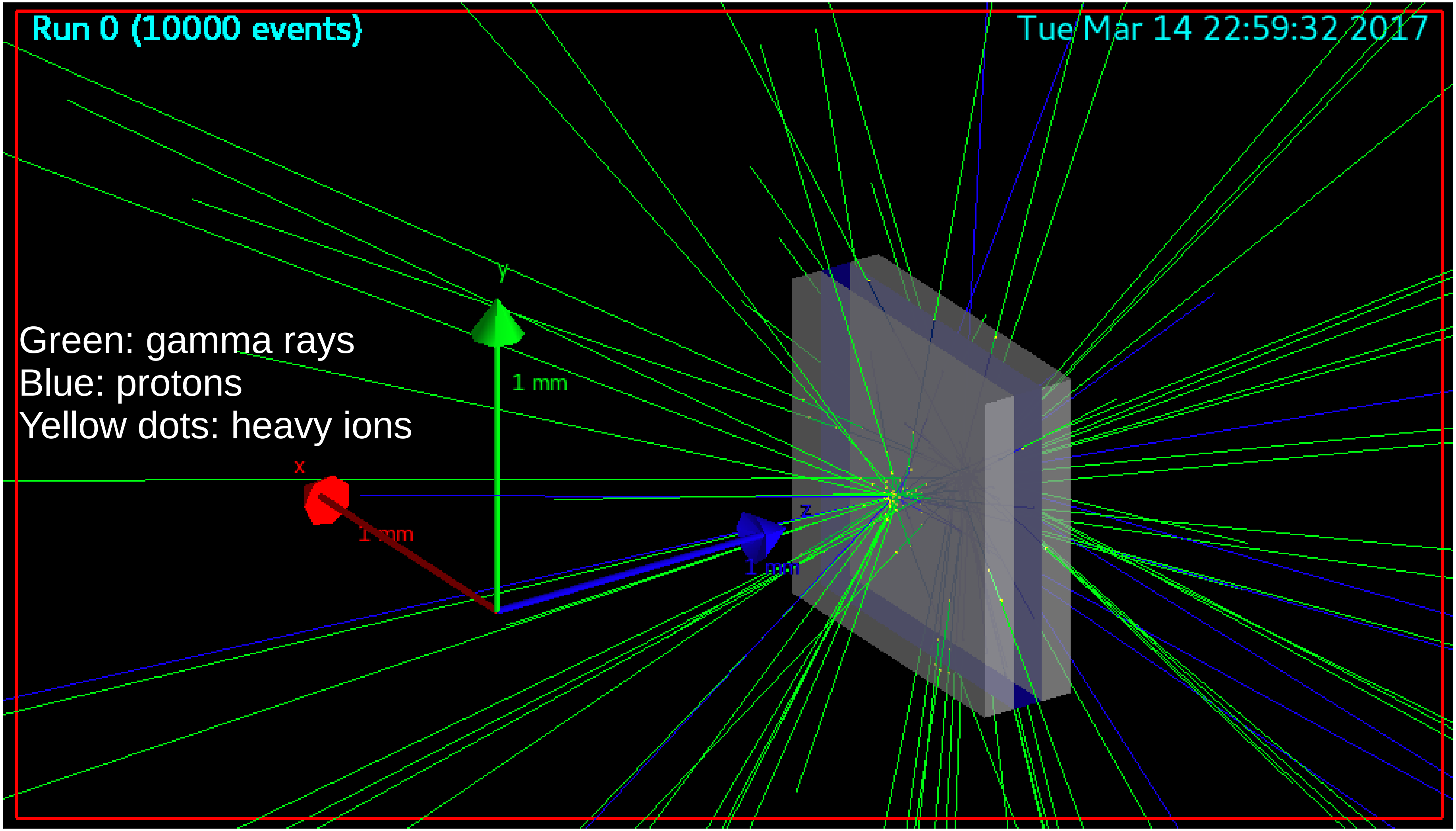
Ray Xu

Mar 17, 2017

Physics Recap

- Incident particle: fast neutrons > 20 MeV
- Neutrons only interact inelastically @ these energies
  - Produces 2ndary particles through “catastrophic” collisions with chip nuclei
  - These 2ndary particles can cause SEU’s via linear energy transfer (LET)
  - … Also what we want to detect to coincide with SEU’s
- Conclusion: optimize detector for the 2ndary, ionizing particles

Geant4 Simulation

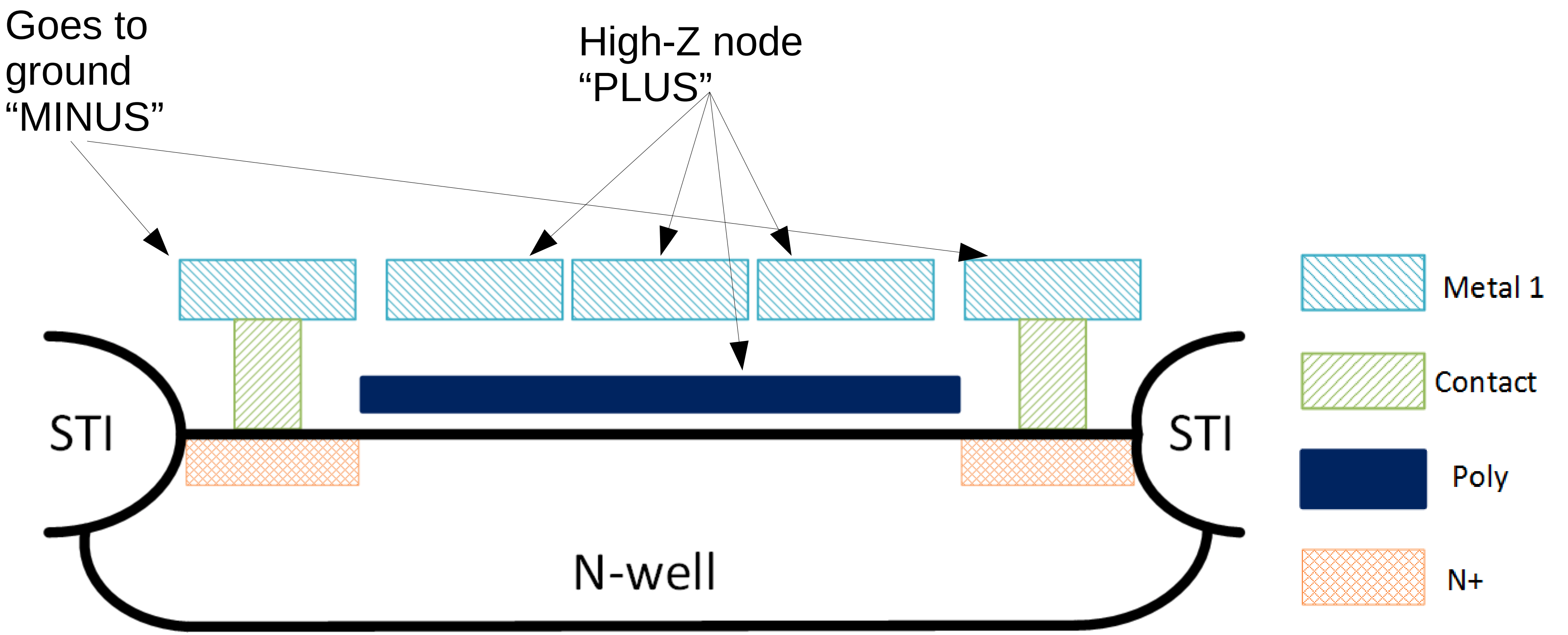


Geant4 Simulation

- 1mm x 1mm parallel-plate capacitor (Cu and SiO_2)
- Bombarded with 100 MeV neutrons (not shown)
- Most collisions occur with the metal
  - Makes sense; copper's nuclei is larger than SiO_2
- At the least: gamma rays and additional neutrons are produced.
  - No LET → good! No SEU.
- At the most: aforementioned + protons, heavy ions of metal/Si/O, other heavy particles (alpha, deuterium, etc)
  - Protons: > 1 MeV
  - Heavy ions: < 1 MeV; < 1 um range
- TODO: Tweak maxStepLength to be able to simulate a more realistic-sized capacitor.

Original Detector Structure

- NMOS varactor + M1 shield (to observe gamma rays by photoelectric/Compton scattering)
- 37 fF (~1 CDAC unit cap) – 270 fF



"Length-wise" x-section view

The University of Texas at Austin

Detector Modifications?

- Major drawback to varactor structure
- Perturbed charge scales with amount of energy transfer, which scales with the “thickness” of the E-field region.
- LET in the thin oxide (~2.6 nm thick) will be very limited compared to MOM cap (~microns thick).
- Try M1-poly MOM cap?

Calculation Example

- Assume: 2ndary particle of one 1MeV proton (conservative energy estimate) passes thru SiO2 in the E-field of a MOM finger capacitor. How much perturbed charge?

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Density: $\rho = 2.32\ [\mathrm{g \cdot cm^{-3}}]$

LET @ 1 MeV in SiO2: $\frac{1}{\rho}\frac{dE}{dx} = 189.8\,[\mathrm{MeV \cdot cm^2 \cdot g^{-1}}]$

$$\Rightarrow \frac{dE}{dx} = 44.03\,[\mathrm{keV \cdot \mu m^{-1}}]$$

Calculation Example

- Assume: 2ndary particle of one 1MeV proton (conservative energy estimate) passes thru SiO2 in the E-field of a MOM finger capacitor. How much perturbed charge?

Ion pair generation energy: $w = 17\ [\mathrm{eV}]$

Charge of ion pair: $q_E = 1.6 \cdot 10^{-19}\ [\mathrm{C}] \Rightarrow \frac{q_E}{w} = 9.41 \cdot 10^{-21} [\mathrm{C} \cdot \mathrm{eV}^{-1}]$

Thickness of M1-PO: $t \approx 0.5\ [\mu\mathrm{m}] \Rightarrow \mathrm{dE} \approx 22.02\, [\mathrm{keV}]$

$$\Rightarrow \Delta Q = \frac{q_E}{w} \cdot \mathrm{dE} \approx 0.21\, [\mathrm{fC}]$$

Compared to thickness of gate oxide of a few nano-meters:

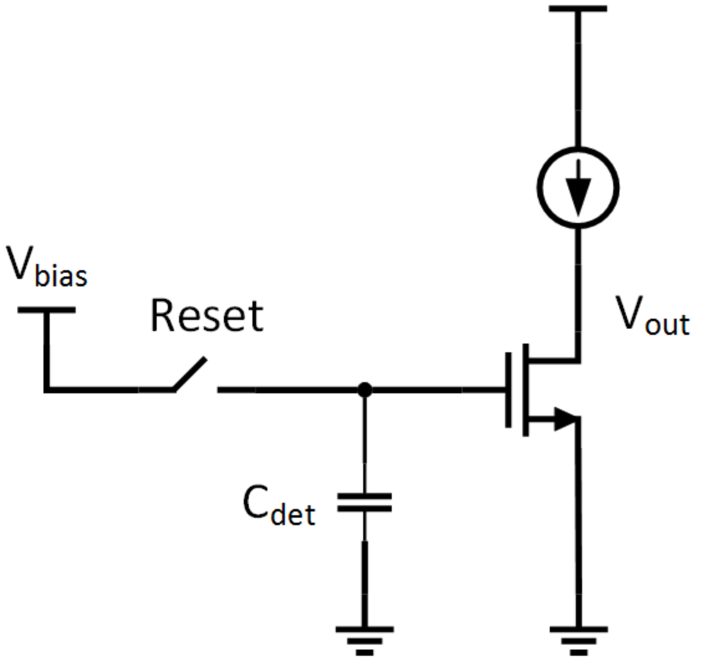
dE ~ [eV]; ΔQ ~ [aC]

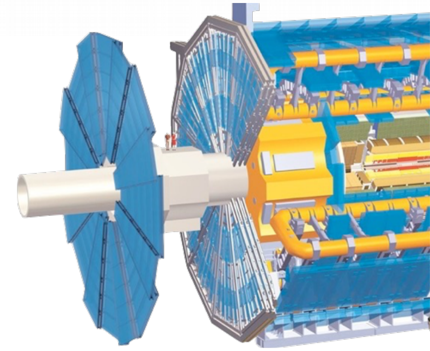
Calculation Example

- M1-PO MOM finger cap of dimensions equal to a CDAC unit cap cell has extracted capacitance of ~20 fF.
- ΔQ Should yield a 10mV perturbation of capacitor voltage if detector capacitor initially charged to half-VDD (600mV)
- Slight problem: dielectric between M1-PO is some “mystery dielectric” with lower ε_r
- But, LET should be on the same order of magnitude…

Detector Readout

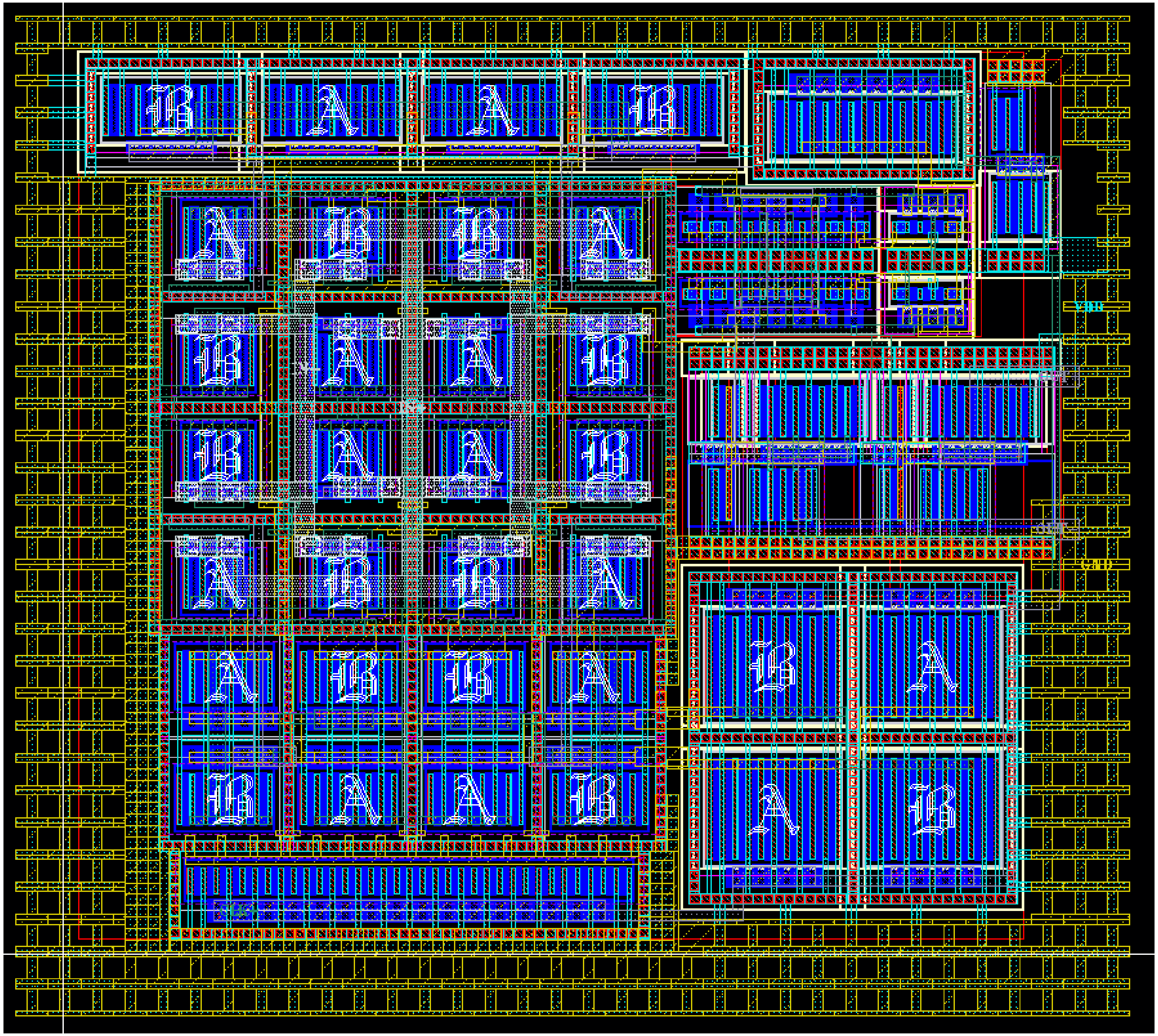
- “Electrometer”
- $C_{gg} << C_{det}$
- Reset sync’ed to sampling clock
- one per detector cap + reference
- TODO: determine BW, noise, and sw. leakage requirement





Layout Update

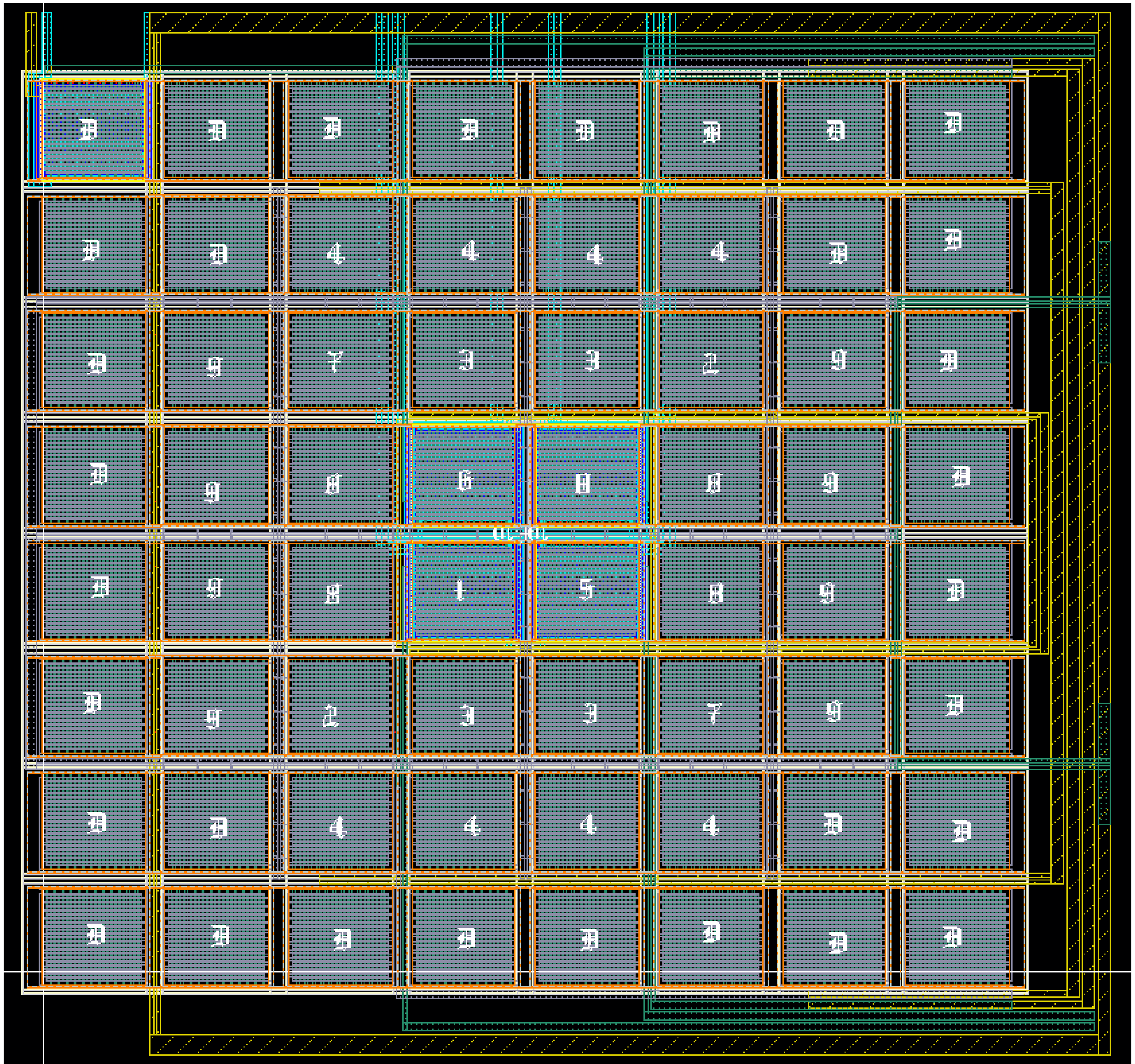
DTC2



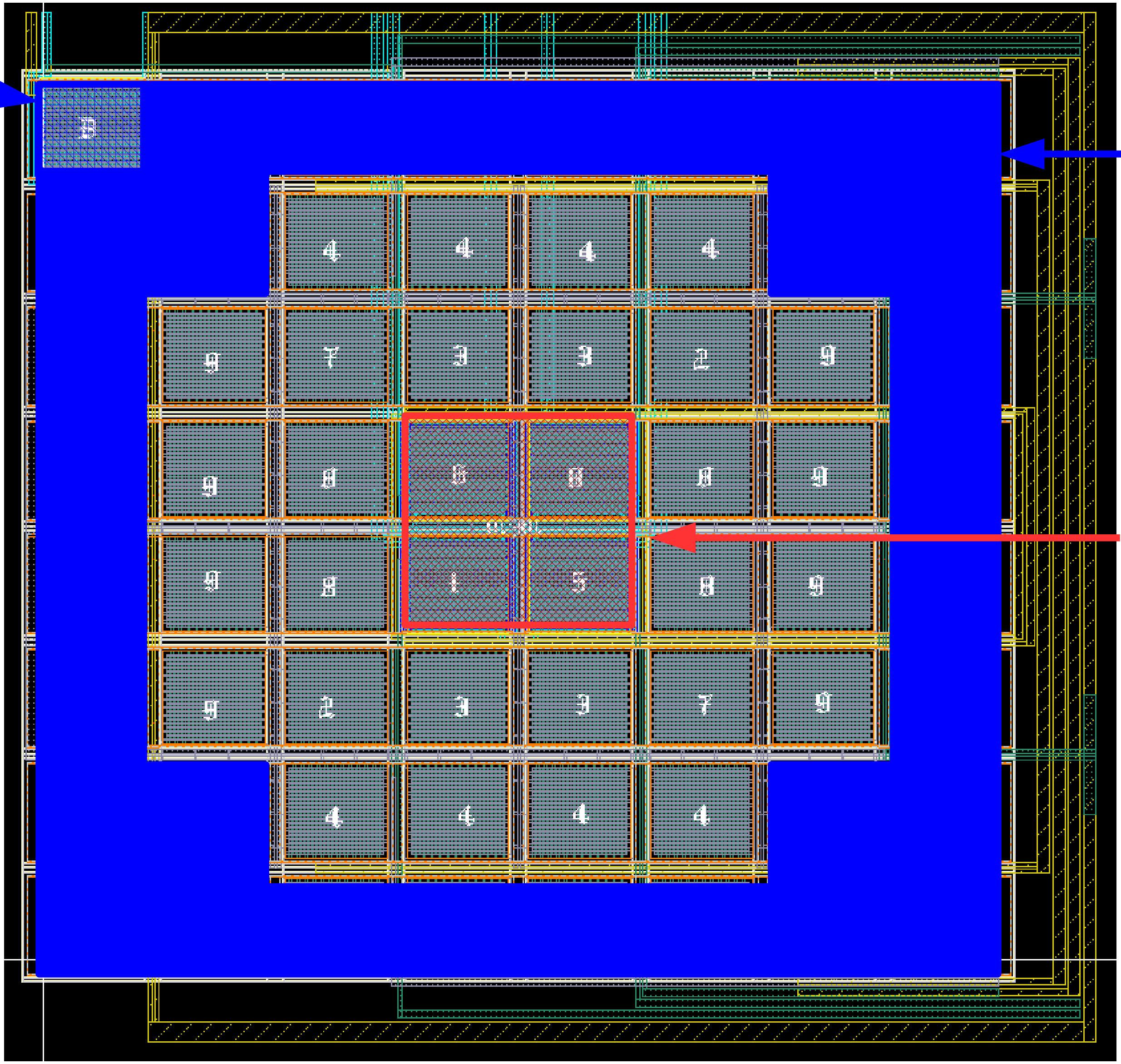
DTC2

- Finalized for 1p6m 3X1Z1U
- Approx 20 um x 20 um
- Common-centroid, taking into account WPE and LOD
- Noise + (systematic) offset < 400 uV
- Worst-cast t_{pd}: $\Delta\mathrm{V}_{\mathrm{in}}$ = 400uV $\rightarrow$ $t_{pd} \approx$ 300 pS
- Power consumption @ 320 MHz clock: 200 uW (?!?!)

CDAC



CDAC



MOM cap + MOSCAP detector (test struct)

Dummy caps

4 CDAC unit caps + MOSCAP detector

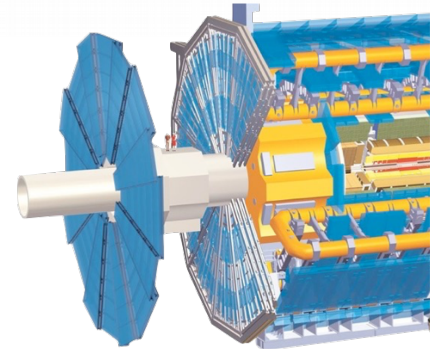
CDAC

- Approx 50 um x 50 um
- All routing done inter-metal-stack (metals 2-4)
- “Alternating” metal routing to reduce uneven parasitics
- Do not use metal 5 (thick metal and copper x-s is larger than SiO2)
- Metal 1 reserved for detector structures
- Parasitic extraction: all cap ratios within 1-2 fF of unit cap
- TODO: Replace MOSCAP with M1-PO MOM detector structure

References

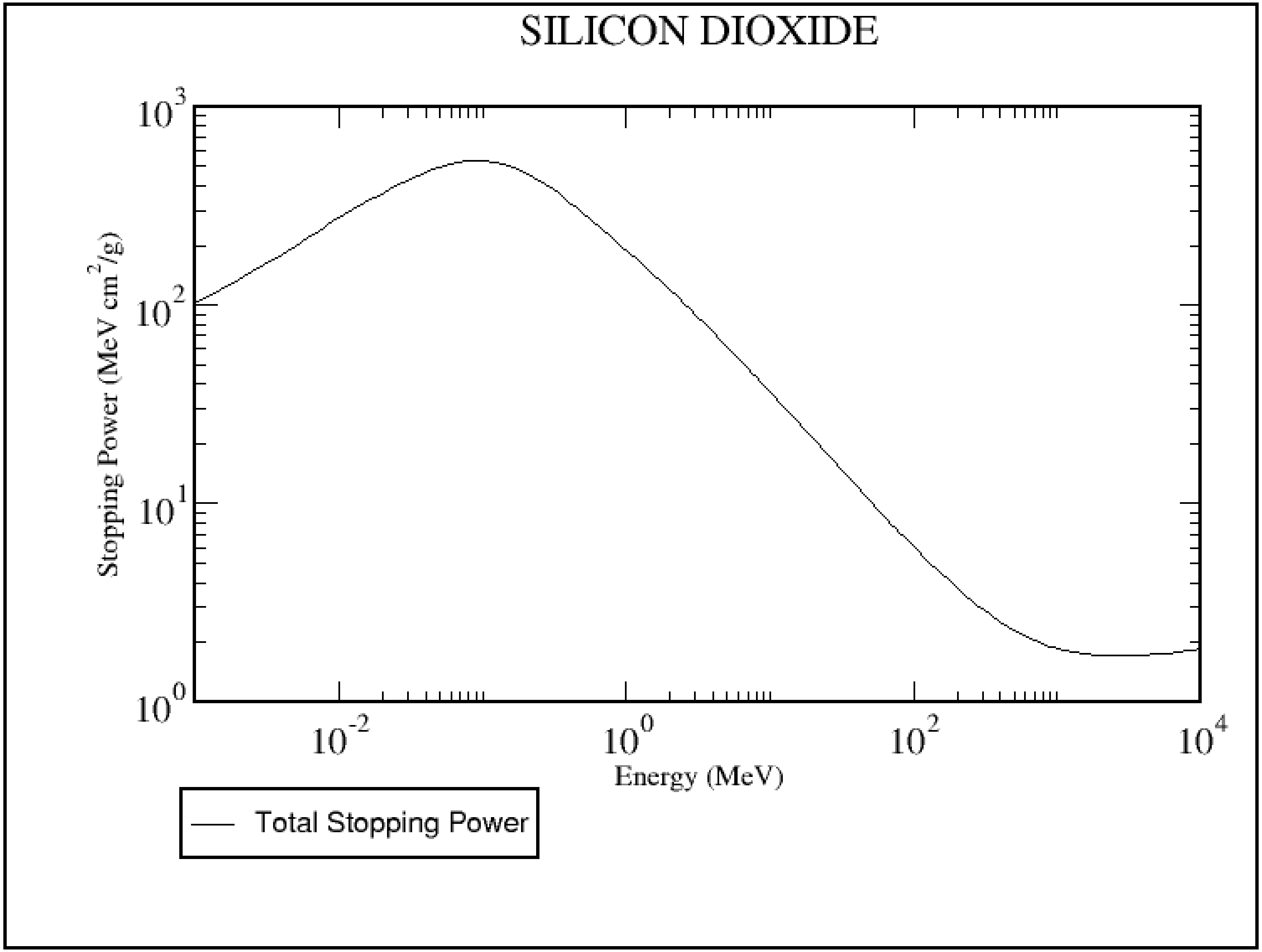
[1] http://holbert.faculty.asu.edu/eee460/IonizationRange.pdf

[2] PSTAR database http://physics.nist.gov/cgi-bin/Star/ap_table.pl

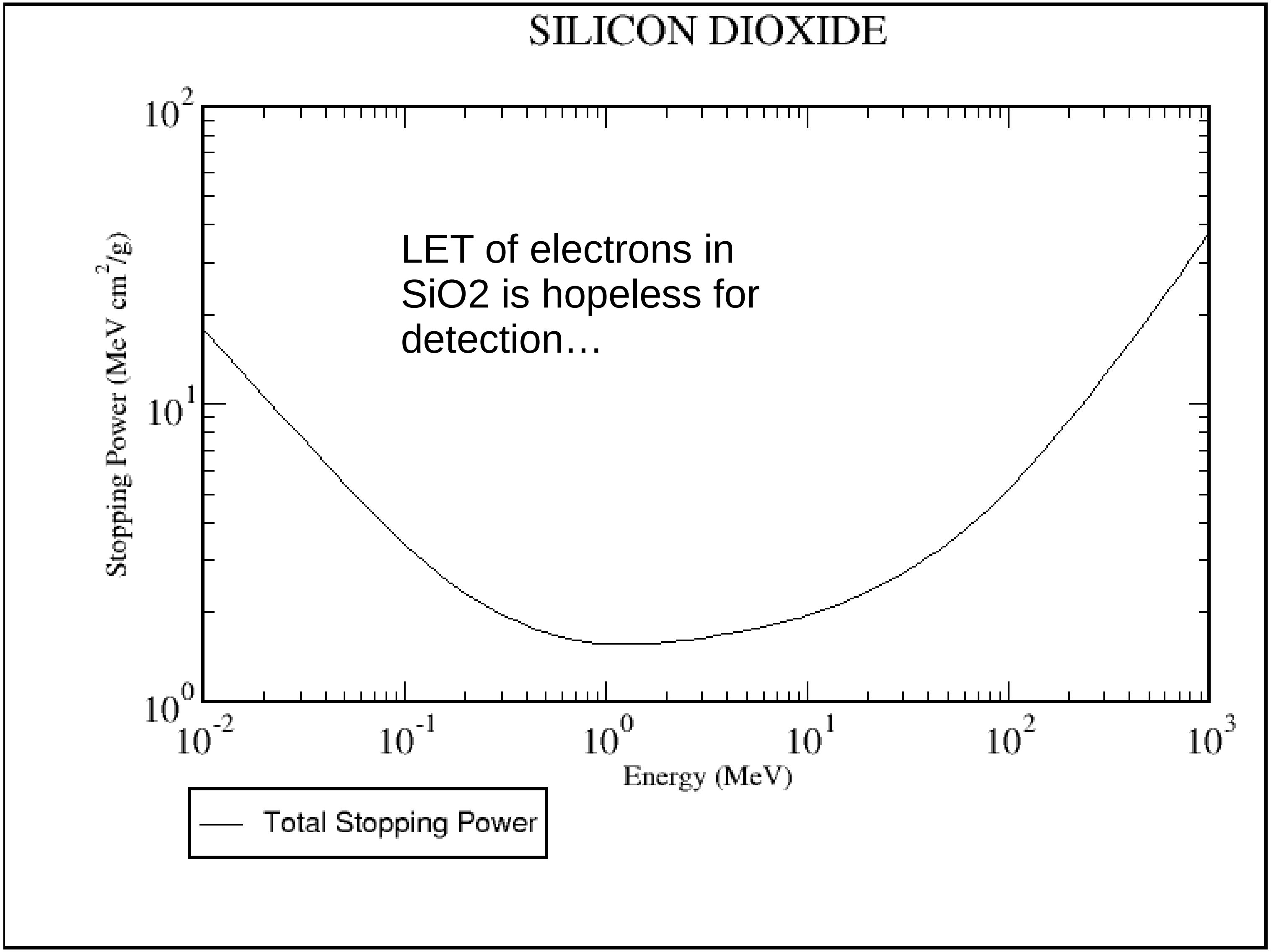


Backup Slides

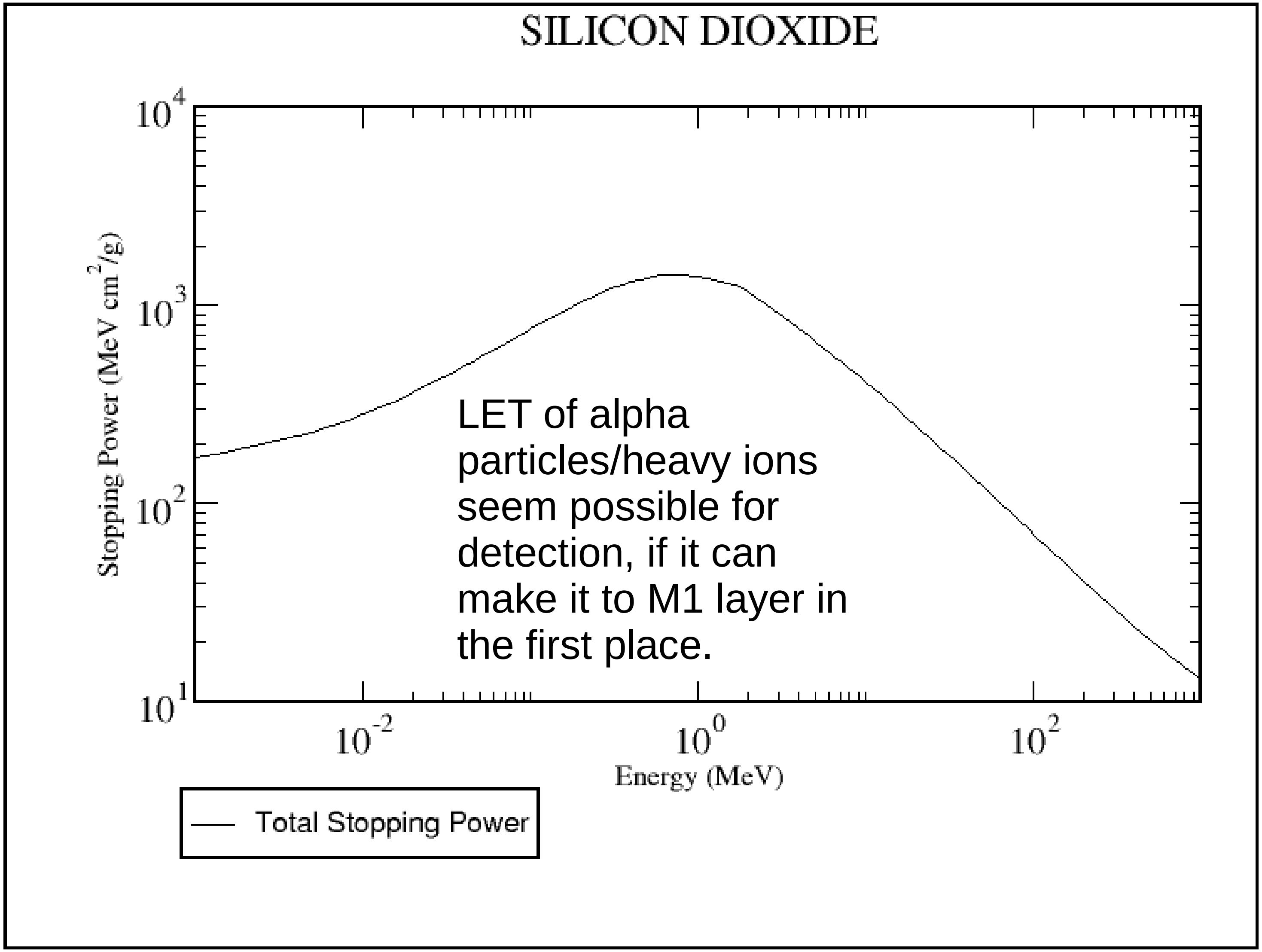
PSTAR Database



ESTAR Database



ESTAR Database



LET of alpha particles/heavy ions seem possible for detection, if it can make it to M1 layer in the first place.